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Fisheries Enhancement Options for Dinosaur Lake, A Review

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EXECUTIVE SUMMARY

Dinosaur Lake is a "run-of-the-river" reservoir which has a steep bottom topography and short water retention period. As such, reservoir productivity is low and the littoral zone is severely limited. Only two tributaries, Johnson and Gething creeks, provide spawning and rearing habitat for fish populations in Dinosaur Lake. Due to poor quality habitat and variable flow regimes, recruitment of sportfish from these systems is low. Entrainment of fish out of Dinosaur Lake, via the Peace Canyon Dam, likely is a significant factor which restricts fish abundance in the reservoir.

Rainbow trout is the predominant sportfish species in the reservoir although other sportfish species are present, their numbers are much lower. The rainbow trout population is supplemented annually with releases of hatchery stock fish. Large populations of lake whitefish and longnose suckers also may be present in Dinosaur Lake. Growth rates of both wild and hatchery stock rainbow trout are good; however, spawning success and survival are low. Rainbow trout utilize Johnson Creek for spawning, whereas Gething Creek is used principally by bull trout. Low survival of rainbow trout is attributed to lack of suitable rearing areas in the reservoir and entrainment out of the system.

Implementation of effective alternatives to enhance sportfish populations in the reservoir will be costly and their effectiveness cannot be predicted with absolute certainty. Enhancement categories include techniques which reduce entrainment, techniques which increase rearing habitat in the reservoir, and techniques to improve spawning habitat. Methods within each category can be priorized based on their effectiveness and costs.

The first step required to increase sportfish numbers in the reservoir is reduction of entrainment. Pen rearing of hatchery fish may be the most effective technique available to achieve this goal. Creation of rearing habitat in the reservoir is the second step which should be considered. Artificial structures (either floating or on the bottom) provide a cost-effective means to create rearing habitat, which presently is severely limited. An additional benefit will be reduced entrainment of fish which utilize artificial structures. Once fish survival in the reservoir has been increased, improvement of spawning habitat should be undertaken. This is of primary importance for maintenance of wild fish populations residing in the reservoir. Although very costly, restoration of the Johnson Creek watershed should be considered before the lower stream can be enhanced. Extreme flow regimes of Johnson and Gething creeks limit the usefulness of habitat restoration in lower sections of both streams. Upstream transport of spawning bull trout above the impassable falls is a viable alternative to habitat enhancement in Gething Creek, as long as suitable habitat exists in the upper watershed. Artificial spawning channels also provide an alternative to tributary enhancement. Although costly, the controlled environment of artificial spawning channels would ensure much higher survival of fry. They create an added benefit by providing valuable rearing habitat for sub-adult fish from Dinosaur Lake.

Choice of which option to implement depends on the long-term management goals for the reservoir's sport fishery. If increasing sportfish densities to improve recreational angling in the reservoir is important, options designed to reduce entrainment and increase habitat should be given highest priority. If maintenance of wild rainbow trout and bull trout populations is critical, then spawning habitat improvement of the tributaries should be given serious consideration.

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1.0 INTRODUCTION

1.1 BACKGROUND

The Peace Canyon Dam is located 20.5 km downstream of the W.A.C. Bennett Dam on the Peace River (Figure 1). The reservoir created by the dam, Dinosaur Lake, impounds 0.216 km^3 of water and has an area of 805 ha. The Peace Canyon project operates as a "run-of-the-river" facility, taking advantage of the storage capacity of the upstream Williston Reservoir rather than its own storage capability. As such, the reservoir level is held near constant with minimal fluctuations (i.e., <2 m) under normal operating conditions.

In April 1980, B.C. Environment and B.C. Hydro signed a memorandum of agreement concerning this project. As part of fisheries compensation, this agreement called for construction of a pilot hatchery which would annually produce 50 000 rainbow trout yearlings for release into Dinosaur Lake. It also was agreed that fisheries inventories and annual creel surveys would be used, in part, to evaluate the effectiveness of the stocking program. At the completion of the evaluation period a decision would be made concerning future fisheries compensation. The pilot hatchery was operational between 1981 and 1989. After its closure, the stocking program centred on using fish from the B.C. Environment hatchery system.

Creel survey information collected from 1984 to 1988 indicated that hatchery stock rainbow trout provided an important contribution to the Dinosaur Lake sport fishery (i.e., approximately 50% of catch). The data also showed that catch rates were consistently low (<0.40 fish/h), and, as a consequence of low catch rates, angler use of the reservoir had decreased. Low survival of fish, due primarily to removal of fish from the system by direct mortality or entrainment out of the reservoir, was the reason given for low catch rates (Hammond 1987a).

1.2 OBJECTIVES

In February 1993, R.L. & L. Environmental Services Ltd. was contracted by B.C. Ministry of Environment, Lands and Parks to assess fisheries enhancement potential of Dinosaur Lake and its tributaries, with the ultimate goals of the study being to assess ways to increase fish numbers in the reservoir and angling opportunities. To accomplish these goals, biophysical studies previously completed in the Dinosaur Lake watershed were assessed, and a literature review was conducted of enhancement projects which have been undertaken in other reservoirs, particularly "run-of-the-river" reservoirs. From this information, recommendations were made concerning enhancement opportunities for Dinosaur Lake and its tributaries. These

recommendations were priorized based on chances for success, cost considerations, and enhancement of wild stock as part of the enhancement option. This report summarizes these findings.

1.3 METHODS

Manual and computerized literature searches were conducted to obtain information from a variety of sources. In addition to reviewing reports supplied by B.C. Environment (Appendix A), acquisitions contained within the R.L. & L. Environmental Services Ltd. library were utilized. Existing information on the Dinosaur Lake watershed included pre-development inventory and impact assessment reports produced by Renewable Resources Consulting Services (1975), Thurber Consultants (1975), and Ash (1976). B.C. Environment completed post development biophysical inventories (Hammond 1984, 1986a, 1987b) as well as creel surveys of the sport fishery between 1984 and 1988 (Hammond 1985, 1986a, 1986b, 1987b, 1988; R.L. & L. 1993). Assessments of fisheries enhancement options were completed by Ash (1976), Wightman and Taylor (1978) and Western Renewable Resources (1988).

A computerized literature search of the Aquatic Science Abstracts database was conducted using the University of Alberta Online Enquiry Service. For the computerized search, we used keywords that included fisheries, reservoir, enhancement, habitat, and stock. Personal contact also was made with J. Hammond and T. Down of B.C. Environment, and D. Wilson of B.C. Hydro concerning their knowledge of the study area and fisheries enhancement options.

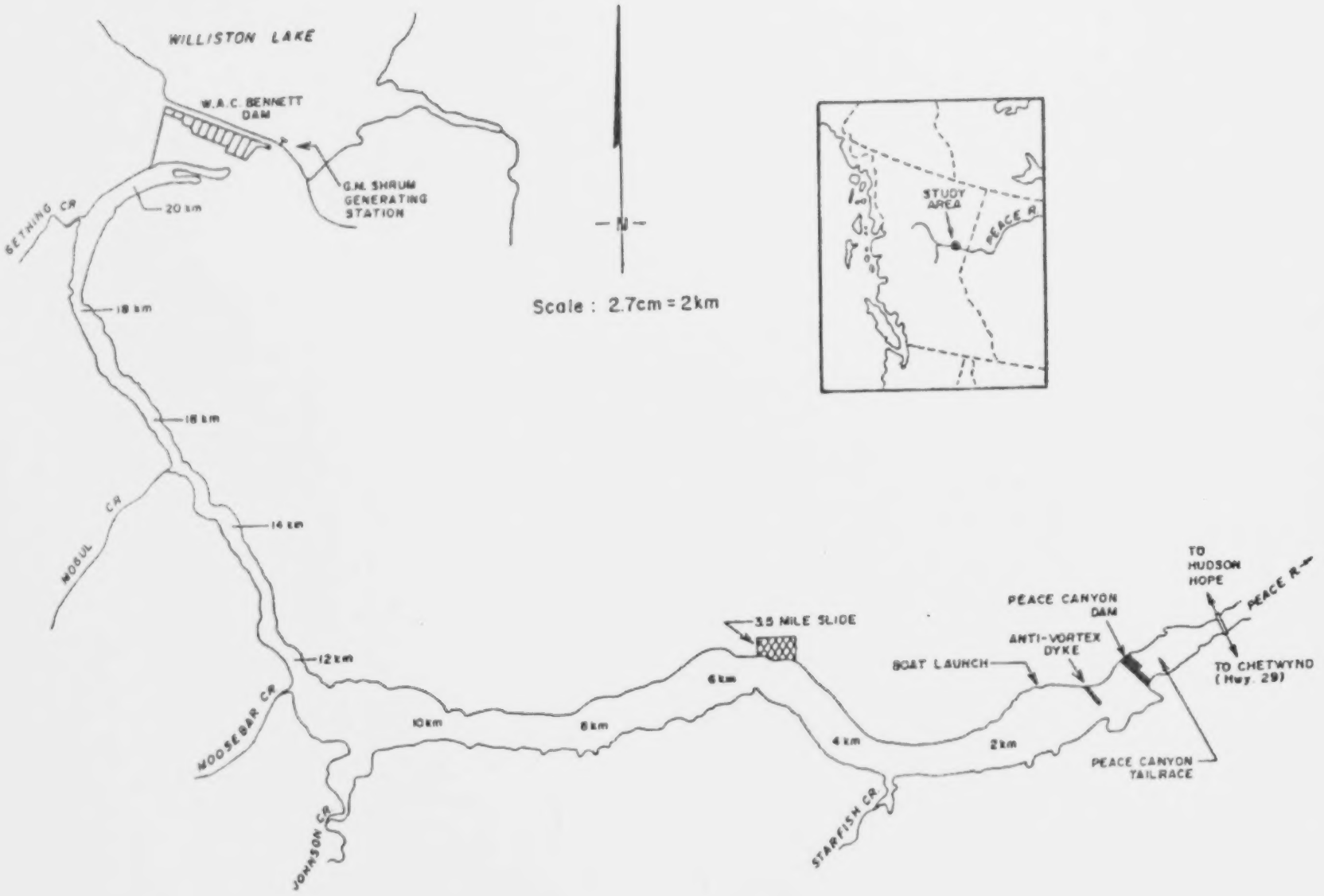

Figure 1 Map and location of Dinosaur Lake.

Source: B.C. Ministry of Environment and Parks, 1988

2.0 HABITAT AND FISH RESOURCES

2.1 HABITAT

2.1.1 Dinosaur Lake

Dinosaur Lake was formed in 1979 after completion of the 46 m high Peace Canyon Dam (Hammond 1984). The reservoir is 20.5 km in length, with the tail-race area of W.A.C. Bennett Dam delineating its uppermost limit. Dinosaur Lake is a "run-of-the-river" reservoir which has a water retention time of approximately three days. Because the generating station at Peace Canyon Dam utilizes instantaneous flow of the river rather than storage in its own reservoir, the reservoir level is held fairly constant under normal operating regimes. Fluctuations in water level generally are less than 2 m.

The surface area of Dinosaur Lake is 805 ha of which approximately 405 ha is former river channel while the remaining 400 ha encompasses steep sided river valley (Hammond 1984). This topography creates a deeply entrenched reservoir with an extremely limited littoral zone.

Oxygen, temperature and nutrient regimes of Dinosaur Lake are dependent on hypolimnetic water releases of W.A.C. Bennett Dam from its storage reservoir, Williston Lake. Dissolved oxygen levels remain close to saturation regardless of depth, and the lake remains isothermal throughout the year. Annual fluctuations in temperature are dampened by the thermal storage capacity of Williston Lake, and thermal stratification does not occur in Dinosaur Lake. Temperature monitoring at the Peace Canyon Dam tailrace indicates that water temperatures of the discharge normally range between 4°C and 14°C during the year (Pattenden 1992). Water temperatures exceed 10°C only between mid-July and early November. The water chemistry of Dinosaur Lake is indicative of oligotrophic, unproductive conditions.

2.1.2 Tributaries

Of five tributaries entering Dinosaur Lake only Johnson and Gething creeks provide spawning and rearing areas for Dinosaur Lake fish.

Johnson Creek

Johnson Creek is the primary spawning and rearing area for rainbow trout (Ash 1976). The creek flows in a northerly direction towards Dinosaur Lake which it enters approximately 10 km downstream of the W.A.C. Bennett Dam. The creek is entrenched in sedimentary deposits of sandstone and shale overlain in many places by gravels, silts, and clays. During 1973, upstream portions of the creek were adversely affected by logging activity. High sediment loads and fluctuating discharge rates were attributed, in part, to this activity (Hammond 1984).

Portions of Johnson Creek's stream banks are prone to slumping, which also contributes to the high sediment load during freshets. Thurber Consultants (1975) stated that evidence of eroding banks, areas of exposed rock, relatively impermeable soil, and small watershed size contributed to marked fluctuations in sediment load, turbidity and discharge levels of the creek.

Fish movement in Johnson Creek is limited to the lower 500 m due to an impassable falls which is 4.6 m in height (Plate 1). Spawning and rearing habitat are available in this section of stream. Two areas of high quality spawning habitat for rainbow trout were identified by Renewable Resources Consulting (1975), along with numerous sections of moderate quality habitat. Limiting factors in these areas included interstitial silt in the gravel, compaction of the substrate, and movement of suitable gravel along the stream bed. Moderate gradients, an abundance of boulders which are velocity breaks, and the presence of pools, provide an abundance of rearing areas for rainbow trout (Plate 2).

The present status of spawning and rearing habitat in Johnson Creek is unknown. Anecdotal descriptions by Wightman and Taylor (1978) and by Hammond (1987b) suggest that habitat quality had decreased since the creek was first surveyed in 1974.

Gething Creek

Gething Creek is the primary spawning area for bull trout and to a lesser extent rainbow trout (Hammond 1987b). Gething Creek, which enters Dinosaur Lake approximately 1 km below the W.A.C. Bennett Dam, is deeply entrenched in sedimentary deposits of sandstone and shale which are overlaid in many places by silts and clay. The gradient of Gething Creek is precipitous, dropping 30.5 m in the lower first kilometre, thereby limiting its value as spawning and rearing habitat. The extent of fish movement into Gething Creek is restricted to the lower 600 m of stream due to a vertical waterfall estimated to be 6 m in height (Plate 3). Several small falls and cascades are present within this section, but are not considered significant barriers to salmonid movement (Ash 1976). Substrate is composed of boulder and angular shale intermixed with areas of gravel (Plate 4).

Plate 1 Impassable falls located on Johnson Creek approximately 500 m upstream of Dinosaur Lake, June 1975.

Plate 2 Typical habitat conditions on Johnson Creek during late spring, June 1975.

Plate 3 Impassable falls located on Gething Creek approximately 600 m upstream of Dinosaur Lake, June 1975.

Plate 4 Typical habitat conditions on Gething Creek during late spring, June 1975.

As for Johnson Creek, some areas of Gething Creek are prone to slumping which contributes to an increased sediment load during high flows. Due to high gradient and large substrate size, a limited amount of spawning habitat exists in Gething Creek. Ash (1976) noted that potential spawning areas were limited by siltation and compaction of the substrate.

Gething Creek is utilized as rearing habitat by rainbow trout and bull trout from Dinosaur Lake and during suitable flow regimes, fingerlings and sub-adults move into the stream during the summer period. Sampling conducted upstream of the impassable falls by Ash (1976) identified suitable spawning areas, but no fish were captured upstream of the falls during extensive sampling, indicating no resident populations of fish were present above the falls.

Other Tributaries

Three small tributaries (Moosebar, Starfish and Mogul creeks) drain into Dinosaur Lake. Spawning and rearing habitat in these systems is severely limited due to intermittent discharges and barriers to fish movement. A fourth tributary, an artificial drainage channel, is located in the picnic area at Bullrun Flats. Discharge from this tributary occurs only during spring freshet and rain events, which makes it of little value to sportfish.

2.2 FISH RESOURCES

Fifteen species of fish have been sampled from Dinosaur Lake (Table 1). Of these, rainbow trout was the only species which has been investigated intensively, and as such, the discussion will centre on this sportfish. Pertinent information for other species also will be examined and summarized.

2.2.1 Rainbow Trout

Stocking

Rainbow trout has been the only sportfish species stocked in Dinosaur Lake (T. Down, pers. comm.). Stocking in the reservoir has occurred annually since 1982 (Table 2). From 1982 until 1989, the stocked fish were raised in the pilot hatchery at Peace Canyon Dam; from 1990 to present, fish were raised in provincial hatcheries.

Table 1 Fish species encountered in Dinosaur Lake (Hammond 1984 and 1986a).

COMMON NAME	LATIN NAME
Rainbow trout	*Oncorhynchus mykiss* (Walbaum)
Bull trout	*Salvelinus confluentus* (Suckley)
Lake trout	*Salvelinus namaycush* (Walbaum)
Kokanee	*Oncorhynchus nerka* (Walbaum)
Arctic grayling	*Thymallus arcticus* (Pallas)
Mountain whitefish	*Prosopium williamsoni* (Girard)
Lake whitefish	*Coregonus clupeaformis* (Mitchill)
Burbot	*Lota lota* (Linnaeus)
Longnose sucker	*Catostomus catostomus* (Forster)
White sucker	*Catostomus commersoni* (Lacépède)
Northern squawfish	*Ptychocheilus oregonensis* (Richardson)
Peamouth	*Mylocheilus caurinus* (Richardson)
Redside shiner	*Richardsonius balteatus* (Richardson)
Slimy sculpin	*Cottus cognatus* Richardson
Spoonhead sculpin	*Cottus ricei* (Nelson)

Table 2 Stocking rates of hatchery rainbow trout in Dinosaur Lake between 1982 and 1992 (from B.C. Environment Release Records Database and Hammond 1987b).

YEAR	RELEASE DATES	BROOD STOCK	FINGERLINGS	FRY	COMBINED
1982	01 May	Dinosaur[a]	16 085	-	16 085
1983	01 May and later	Dinosaur and Williston[b]	25 711	24 293	50 004
1984	01 May and later	Williston	62 920	41 332	104 252
1985	28-30 April	Dinosaur and Williston	33 476	-	33 476
1986	04-07 May	Williston	65 841	-	65 841
1987	18 April and later	Dinosaur and Williston	46 455	-	46 455
1988	19 April and later	Dinosaur and Williston	73 373	-	73 373
1989	19 April and later	Tunkwa	22 233	-	22 233
1990	19 June	Premier	40 000	-	40 000
1991	18 June	Premier	40 000	-	40 000
1992	23 June	Premier	40 000	-	40 000

[a] Johnson Creek Stock

[b] Blackwater Creek Stock

Stock was obtained from a variety of sources (Table 2). Dinosaur stock, collected from Johnson Creek, were utilized initially. By the second year of brood collection, Williston stock from Blackwater Creek in the Parsnip River drainage also was obtained. These were probably used since sufficient brood were not available from Johnson Creek (T. Down, pers. comm.). During the 1988 brood year, a switch was made to Tunkwa stock which originated from provincial hatcheries and not from the Peace River watershed. The switch to Tunkwa stock presumably was made because of increasing difficulty in obtaining sufficient brood locally (T. Down, pers. comm.).

Release dates in a given year varied. From 1982 to 1989, hatchery fish were released in late April or early May. From 1990 to present, releases have been delayed until early June. Release locations also varied between years. During 1982, 1983, and 1984, fish were released at the Bennett Dam tailrace, at the boat launch near Peace Canyon Dam, and in Gething and Johnson creeks (Hammond 1987b). From 1985 until 1989, the predominant release location was the Bennett Dam tailrace. The sites utilized since 1990 have also included the bay areas of Johnson and Gething creeks, in addition to the tailrace of the Bennett Dam (T. Down, pers. comm.).

Abundance

Rainbow trout is the predominant sportfish species in Dinosaur Lake. The naturally occurring rainbow trout population which existed prior to impoundment has been supplemented with annual releases of hatchery stock since 1982. The contribution of hatchery stock to the catchable rainbow trout population varied but was approximately 50% during most years (creel census data 1984-1988). The current size of the rainbow trout population in the reservoir is unknown. It is dependent on the number of hatchery fish stocked during any given year and recruitment of wild fish into the system, either through natural reproduction or entrainment through the W.A.C. Bennett Dam. Entrainment of fish out of Dinosaur Lake also is a factor influencing population size.

Using tag returns from harvested fish, Hammond (1986a) estimated the rainbow trout population to be 16 854 fish during 1984; however, this estimate may not be accurate due to removal of tagged fish from the sample through entrainment, tag loss or mortality. Intensive sampling of ideal habitats within the reservoir suggested that rainbow trout were much less abundant than the estimate indicated (Hammond 1986a). Low catch rates (i.e., <0.40 fish/h) by anglers utilizing the reservoir provides additional evidence that population levels are low.

Distribution

Rainbow trout distribution within Dinosaur Lake is not random. During inventories by B.C. Environment personnel, most adult fish were encountered in the W.A.C. Bennett Dam tailrace. Reasons given for this phenomenon were higher availability of food, suitable water temperatures, activities related to spawning, and barriers to upstream movement.

Investigations of movements by hatchery fish also show a distinct pattern (Hammond 1987b). Newly released fingerlings rapidly disperse downstream. During 1986, fish released immediately below the W.A.C. Bennett Dam required only a few weeks to move downstream to tributaries such as Johnson and Starfish creeks. Within one and a half months of release, some hatchery fish were encountered downstream of the Peace Canyon Dam, indicating they had passed through the dam.

These investigations also showed that fingerlings rapidly ascended all available tributaries (i.e., Johnson, Gething, Moosebar and Starfish creeks) after release in the reservoir.

Survival

Survival of rainbow trout in Dinosaur Lake is apparently low and variable. During 1986, survival rates of hatchery fish did not exceed 1 % (Hammond 1987b). The author suggested that loss of fingerlings from the system was due to high mortality caused by the absence of suitable rearing areas in the reservoir (i.e., severely restricted littoral zone), or more likely, entrainment of hatchery fish through the Peace Canyon Dam.

Natural recruitment of wild fish into the population also is highly variable. Natural reproduction occurs only in Johnson and Gething creeks, and recruitment from these systems is low. Only limited sections of these streams are accessible to fish due to impassable falls, and the habitat quality within these sections is poor. Recruitment from these systems also is dependent on annual flow regimes. Complete year-class failure during 1983 was attributed to flood events which caused stream bed movements and scouring (Hammond 1984). In contrast, fry and sub-adults were sampled from these two creeks during 1986, a year without flood events (Hammond 1987b). Natural recruitment of wild stock from these creeks is probably insufficient to maintain Dinosaur Lake sportfish populations on an annual basis. It is likely that entrainment of wild fish from Williston Lake provides a significant contribution to the wild stock each year.

Sexual Maturity and Spawning

Rainbow trout sexually mature by age 3 in Dinosaur Lake (Hammond 1986a), but mature fish may not spawn every year. The occurrence of ripe fish in the reservoir throughout the summer period suggests that environmental factors, such as abnormal changes of water temperature, have altered spawning chronology — a phenomenon which has been observed in other rainbow trout populations residing below dams (Hildebrand 1991). Inventories by Hammond (1984, 1986a, 1987b) also documented the presence of numerous female rainbow trout containing residual eggs. The author suggested that an altered temperature regime or limited spawning habitat may have caused these fish to abort their attempts to spawn.

Spawning by rainbow trout likely does not occur in Dinosaur Lake proper (Hammond 1984) or the tailrace area of the W.A.C. Bennett Dam (Ash 1976). Johnson Creek is the major tributary used by this species, while Gething Creek is utilized to a much lesser extent. In 1983, the total spawning run of wild fish in Johnson Creek was approximately 100, while at Gething Creek approximately 30 fish were captured (Hammond 1984). In 1986, only four mature fish were encountered in Johnson Creek. This dramatic reduction was attributed to very poor recruitment during 1983, when flood events caused extensive scouring and substrate movement.

Age and Growth

Rainbow trout in Dinosaur Lake exhibit good growth rates compared to other northern rainbow trout populations (Hammond 1986a). As well, hatchery and wild fish grow at relatively similar rates which suggest that, at present population levels, competition between these two stocks is probably negligible. Maximum sizes attained by both stocks are approximately 370 mm fork length and fish rarely exceed five years of age.

Food Habits

Zooplankton is the major food item for all size-classes of rainbow trout in Dinosaur Lake (Hammond 1987b), but only from mid-summer to early fall when larger zooplankters (i.e., *Hetercope septentrionalis* and *Daphnia pulex)* are available. Most of the Zooplankton is entrained from Williston Lake since the short water retention time limits production within the reservoir. Prior to the appearance of Zooplankton, rainbow trout feed on benthic organisms and winged-insects. In contrast to wild fish, newly released hatchery stock did not feed until winged-insects became available on the surface in late May (Hammond 1987b). Because fish from the pilot hatchery were released as early as late April, these individuals may not have commenced feeding for up to one month. Currently, hatchery fish are released in late June to ensure that food is available to trout in the reservoir (T. Down, pers. comm.).

Rearing Areas

Due to the extremely limited littoral zone in Dinosaur Lake, few juvenile fish appear to rear in the reservoir proper (Hammond 1987b). Major tributaries available for rearing are Johnson and Gething creeks. Moosebar, Mogul, and Starfish creeks also are utilized when flows are suitable; however, intermittent flows and barriers to fish movement severely limit the usefulness of these three creeks as rearing habitat. Fingerling and sub-adult fish (particularly hatchery stock) exhibit distinct movements into all available tributaries during early summer.

2.2.2 Lake Whitefish

Lake whitefish is likely the second most abundant fish in Dinosaur Lake, but little information is available for this species. Sampling by Hammond during 1983 and 1984 indicated that whitefish were very abundant but few fish were encountered during 1986. It is not known whether this change in abundance was real or an artifact of sampling conditions.

Because young lake whitefish are predominately planktivorous, they are able to exploit the major food resource (Zooplankton) available in Dinosaur Lake.

This species probably does not spawn in the reservoir despite the presence of suitable habitat at the tailrace of the W.A.C. Bennett Dam. Extensive sampling by Pattenden et al. (1990, 1991) in the Peace River just downstream of Dinosaur Lake failed to produce either ripe individuals or juvenile fish, even though the study area contained a very large lake whitefish population. It is suspected that maintenance of the Dinosaur Lake population of lake whitefish is achieved by entrainment of individuals from Williston Lake.

2.2.3 Bull Trout

A small population of bull trout exists in Dinosaur Lake. These fish were encountered infrequently in the reservoir during inventories but mature adult spawners were captured from Gething Creek in 1983 (40 fish) and 1986 (18 fish). Gething Creek also is utilized for rearing by this species.

2.2.4 Kokanee

Small numbers of kokanee are present in Dinosaur Lake. Because they are planktivorous and are pelagic, they are not well suited to a "run-of-the-river" environment. Since the species was first encountered

in 1984, its population size has not increased. Absence of suitable spawning habitat and entrainment of individuals out of the system are potential reasons why there has been no significant increase.

2.2.5 Longnose Sucker

Longnose sucker is the predominant non-sportfish species residing in Dinosaur Lake, but only limited information is available for this species. During 1983 and 1984, suckers along with whitefish predominated the fish community in the reservoir; however, their numbers were much lower during 1986 (Hammond 1987b). Longnose suckers were particularly abundant at creek mouths. During spring and early summer these concentrations represented mature fish which entered the creeks to spawn.

Longnose suckers utilized both Johnson and Gething Creeks for spawning purposes and may compete with species such as rainbow trout (i.e., disruption of redds, displacement of adults from holding pools, predation of eggs and young).

2.2.6 Other Species

Other sportfish species which had only small remnant populations in the reservoir included mountain whitefish, Arctic grayling, and lake trout. Lack of suitable spawning habitat and the absence of a riverine environment are the principle reasons for the demise of the first two species which were abundant in the Peace River prior to reservoir creation (Thurber Consultants 1975). Small numbers may still exist in the riverine habitat provided by the tailrace of the W.A.C. Bennett Dam. Lake trout, on the other hand, are probably transients, having been entrained from Williston Lake.

2.3 LIMITATIONS TO FISH PRODUCTION

2.3.1 Food

Due to the steep topography of Dinosaur Lake, its littoral zone is severely limited. As a consequence, benthos production within the reservoir is minimal which reduces food availability. The diet of rainbow trout in Dinosaur Lake is composed mainly of large Zooplankton during the summer period, yet production of Zooplankton within the reservoir is severely restricted by the short water retention period (three days). As such, levels of this food source are dependent on inputs from Williston Lake. Factors influencing Zooplankton input include discharge rates through the W.A.C. Bennett Dam turbines, and most importantly, use of the dam's spillway. Hammond (1986a) observed a distinct increase in Zooplankton density when the spillway

of the dam was opened, thereby releasing warmer surface waters out of Williston Lake. Cropping of this food source also may limit its availability to rainbow trout. During periods of low Zooplankton density, efficient planktivores such as kokanee and lake whitefish may compete with rainbow trout for this food source. At present population levels, both hatchery and wild stock rainbow trout exhibit good growth rates. If the population size of rainbow trout is increased through higher stocking rates, it may exceed the capacity of this food source. This could lead to increased competition, and in turn, lower growth rates.

2.3.2 Spawning and Rearing Habitats

Due to its steep bottom topography, spawning and rearing habitats are severely limited in Dinosaur Lake. Johnson and Gething creeks are the only tributaries which provide spawning and rearing habitats for wild rainbow trout and wild bull trout. Due to impassable falls on each stream, only short sections are available to fish and annual recruitment from these tributaries is highly variable. Variable flow regimes and high sediment loads have had a detrimental impact on spawning and rearing success of these species. During 1983, flood events caused severe erosion and stream bed movement in both streams. Hammond (1984) attributed extremely low rainbow trout production during that year to these flood events. In 1986, a year without serious flooding, successful production of rainbow trout and bull trout occurred (Hammond 1986a).

The current state of habitat quality in these tributaries is unknown; however, previous investigations indicated that it decreased between the mid-1970's and 1980's (Ash 1976; Hammond 1987b). Hammond (1987b) described siltation and compaction of spawning gravels as serious problems in both creeks.

The suitability of Johnson and Gething creeks as spawning and rearing areas also may be adversely affected by the presence of other species during critical periods. Ash (1976) identified longnose suckers and slimy sculpins as potential competitors and/or predators of rainbow trout in Johnson Creek. Longnose suckers may compete for spawning sites, physically displace trout by utilizing holding areas or predate trout eggs and fry. Slimy sculpins may prey directly on rainbow trout eggs and fry, or more likely, would compete for food resources in the creek.

2.3.3 Entrainment

Survival of hatchery rainbow trout in Dinosaur Lake is extremely low. During 1986, survival rates of hatchery fish did not exceed 1%. Hammond (1987a) discussed two potential reasons for this low survival. One possible reason was the absence of rearing areas (i.e., restricted littoral zone) in the reservoir. The most significant cause of low survival, however, was loss of fish from the system by entrainment of recently stocked hatchery fish.

Hammond (1987b) monitored the speed of downstream movement by newly released hatchery fish. Fingerlings released at the W.A.C. Bennett Dam tailrace were captured near the Peace Canyon Dam within three weeks. Within one and half months these fish were captured downstream of the Peace Canyon Dam. This provides strong evidence that newly released hatchery fish were leaving the system. The number of hatchery stock fish being lost could not be assessed. During a creel survey of the Peace River sport fishery immediately downstream of Dinosaur Lake conducted in 1985, 38% of the rainbow trout harvested by anglers were hatchery fish (Hammond 1986c). Intensive sampling of the Peace River in the same area showed that during 1989, 28% of all rainbow trout captured were of hatchery stock, while during 1990 the proportion increased to 55% (Pattenden et al. 1990, 1991). Clearly, significant numbers of hatchery fish have been entrained through the Peace Canyon Dam.

Several reasons may explain why entrainment occurs. Newly released hatchery fish exhibit a rapid downstream movement, a phenomenon which has been documented in other "run-of-the-river" reservoirs (Huston and Vaughn 1968; Slaney 1989). Also, during initial years when the hatchery fish were stocked in April, the newly released hatchery fish did not feed for approximately one month after release. Possibly fingerlings that move downstream with the current in search of suitable habitat and food, eventually find their way into the intake ports of the Peace Canyon Dam and are passed out of the reservoir.

2.4 SUMMARY

Environmental characteristics of Dinosaur Lake present a unique set of problems which must be addressed before sportfish populations in the reservoir can be increased. These include steep topography and short water retention time which severely limit reservoir productivity, and the availability of rearing habitat. Tributaries entering Dinosaur Lake provide only limited amounts of spawning and rearing habitats, and recruitment from these streams varies significantly depending on annual flow regimes.

Superimposed on these environmental limitations are the effects of entrainment on the system. Recruitment of wild sportfish into the population is largely dependent on the influx of fish from Williston Lake. Loss of sportfish, particularly newly released hatchery rainbow trout through the Peace Canyon Dam, may significantly reduce fish numbers in Dinosaur Lake.

To increase sportfish densities in Dinosaur Lake, three major constraints must be addressed: entrainment of fish out of the reservoir, severely restricted rearing habitat, and limited spawning habitat.

3.0 REVIEW AND EVALUATION OF ENHANCEMENT ALTERNATIVES

This section provides a review and evaluation of enhancement alternatives which are available to increase fish numbers in Dinosaur Lake. These alternatives were formulated based on biophysical information of the system, a brief literature review, and discussions with B.C. Environment personnel. Detailed cost-benefit analyses were not provided as this was beyond the scope and budget of the study; however, each option has been evaluated based on its relative cost and effectiveness.

Enhancement options have been categorized into three groups — methods to reduce entrainment, methods to increase rearing habitat within the reservoir, and ways to increase availability of spawning habitat. Enhancement alternatives have been priorized within each of these categories, but have not been priorized in relation to options discussed in other categories. This approach was taken because the goals represented by each category differed. For example, the primary goal of creating spawning habitat is to increase recruitment of fish into wild populations, whereas reducing entrainment is designed to increase overall fish numbers, but may not improve recruitment into wild populations.

Implementation of enhancement alternatives may not achieve the ultimate goal of significantly increasing numbers of catchable fish in Dinosaur Lake. At present population densities, growth rates of wild and hatchery stock rainbow trout are good which indicates that competition is minimal between the stocks (Hammond 1987b). The carrying capacity of Dinosaur Lake is unknown but its environmental characteristics suggest that it cannot support very high densities of sportfish. As such, if fish densities are increased through enhancement, the carrying capacity of the system may ultimately limit the effectiveness of the enhancement.

3.1 METHODS TO REDUCE ENTRAINMENT

3.1.1 Deflectors

Significant numbers of fish are lost from Dinosaur Lake by entrainment, particularly hatchery fingerlings. Review of provisions for fish protection at dams, water diversions, and intakes include those of Burns (1966), Either (1970), and Stone and Wester Engineering Corp. (1986). Numerous methods have been used to direct or guide fish. These include light, sound, bubbles, mechanical screens, electrical screens, and louvres. The latter three methodologies have been reviewed and described by Semple and McLeod (1976).

Diversion of fish away from the spillway or intake ports of the Peace Canyon Dam is not likely to be practical. Mechanical screens (i.e., deflectors, travelling screens, etc.) probably would be the only viable

method and are extremely expensive. A review by R.L. & L. Environmental Services Ltd. (1992) of fish diversion systems of hydroelectric projects, identified construction costs to be between 10 and 30 million dollars. As it is desired to keep fish collected by the diversion system in the reservoir, additional costs would be incurred due to transport of these fish upstream away from the Peace Canyon Dam. Deflectors and screens also would require continual maintenance, increasing the operating cost. Thus, installation of deflectors or screening to prevent fish loss by entrainment is not considered feasible.

3.1.2 Stocking Strategies

Stocking is the principle management technique to increase fish numbers in reservoirs (Benson 1982; Huston 1985; Keith 1986). This strategy has been utilized extensively in British Columbia to successfully improve sportfish populations. Unfortunately, stocking programs for Dinosaur Lake and other "run-of-the-river" reservoirs have not been entirely successful (e.g., Cabinet Gorge on the North Clark River in Montana and Hayward on the Stave River in British Columbia). The major reason given for poor success has been loss of fish from the system by entrainment (Huston 1985; Slaney 1989; Hammond 1987a). The stocking program for Dinosaur Lake, therefore, should be designed to reduce the risk of entrainment by hatchery fish as opposed to simply increasing the number of fish stocked. Several strategies are available to the fisheries managers to achieve this goal.

Species

Rainbow trout has been the only fish species stocked in Dinosaur Lake since its creation in 1979. This species was chosen due to its ease of hatchery production, value as a sportfish and its biological characteristics which make it well adapted to cool temperatures of Dinosaur Lake. Other fish species which are favoured by anglers in northeastern B.C. include brook trout, lake trout, bull trout, kokanee, Arctic grayling and walleye. Of these species, only rainbow trout and kokanee are cultured extensively in the province (Western Renewable Resources 1988). Kokanee are not considered a suitable alternative for stocking in Dinosaur Lake. Its pelagic behaviour would make this species very susceptible to entrainment. Bull trout is another potential candidate for artificial propagation. Because this species usually requires stream habitat for rearing purposes, and this habitat is extremely limited, survival of stocked bull trout would likely be very low. In addition, obtaining brood stock would be problematic as it would not be acceptable to use brood from another watershed (T. Down, pers. comm.).

Strain

Researchers have documented differences in migratory tendencies and survival between strains of rainbow trout (Cordone and Nicola 1970; Hepworth and Lepnik 1979). Huston and Vaughn (1968) documented greater downstream movement by Montana State rainbow stock than commercial stock in a "run-of-the-river" reservoir in Montana. It may be appropriate to test different strains of hatchery trout in Dinosaur Lake to assess their tendency for downstream movements.

Brood for Dinosaur Lake fish have been obtained from several wild stocks (T. Down, pers. comm.). During 1982 to 1988, brood was obtained from two sources, Johnson Creek in Dinosaur Lake, and Blackwater Creek in Williston Lake. Since that time, stocks from outside the Peace River watershed have been utilized. It is possible that fish from these stocks have less tendency to move downstream, but the data are not available to assess this possibility. Non-migrating rainbow trout populations could be used to supply brood stock for hatchery production. Stream resident wild rainbow trout populations are likely candidates but wild brood stock are becoming difficult and costly to obtain (T. Down, pers. comm.).

Size at Release

The initial size of fish stocked in reservoirs influences fish survival and growth. The general procedure in British Columbia is to stock reservoirs containing competitive or predatory fish with spring yearlings, and productive mono-culture lakes with fall fry or spring yearlings (Western Renewable Resources 1988). In lakes which have high angling pressure, catchable fish also can be stocked. The Dinosaur Lake stocking program has utilized spring yearlings to maintain the rainbow trout fishery. An alternative may be stocking of larger sized fish; larger fish, are presumably, more capable of maintaining themselves in the riverine environment of Dinosaur Lake.

Release Location and Schedule

Return rates of hatchery fish stocked in Dinosaur Lake were related to release location (Hammond 1987b). Fish released the farthest upstream exhibited the greatest return rates in the angler catch, and hatchery fish released nearest to Peace Canyon Dam were not captured by anglers. These results suggest that entrainment of hatchery fish is minimized by release near the tailrace of the W.A.C. Bennett Dam. This release location and the inlets of Johnson and Gething creeks are currently being utilized as release sites (T. Down, pers. comm.).

Because newly released hatchery fingerlings tend not to feed until winged-insects become available in late May (Hammond 1987b), it is advisable to delay releases until after this period. This has been incorporated into the release schedules since 1990; hatchery fish are not released until late June (T. Down, pers. comm.).

Pen Rearing

Pen rearing is an alternate form of stocking which entails rearing of hatchery fish in a waterbody as opposed to in an artificial hatchery environment — a process very similar to fish culture techniques utilized in coastal British Columbia. This method has been used in a number of reservoirs in British Columbia and the United States. Stocking programs in Europe utilize this system as an alternative to conventional hatcheries, and rainbow trout reared in pens in English reservoirs may be cheaper to produce than those reared in hatcheries (Jarrams et al. 1980). "Cove culture" is a common feature of Chinese reservoirs. Small coves are blocked off by nets and are used to rear fish until they achieve a harvestable size (Xiangke 1986).

Pilot pen rearing programs are currently underway in Alouette and Buntzen lakes, two reservoirs located in southwestern British Columbia (D. Wilson, B.C. Hydro, pers. comm.). B.C. Environment and B.C. Hydro initiated these projects in an attempt to increase the survival of hatchery fish which would improve recreational fishing. Fingerling rainbow trout are maintained in 6.0 X 6.0 m floating pens equipped with automatic feeders. After one year of growth, fish are released into the reservoir. The Buntzen Lake pilot study, which began with 5 000 fish during the first year, was subsequently expanded to 15 000 fish. Total cost (i.e., capital expenditures and maintenance) of production was estimated to be $1/fish. Due to the limited number of released fish during the initial year of the project, the survival of released fish to creel is not known. A creel census has been planned for Buntzen Lake to answer this question.

A pen rearing pilot facility is planned for Hayward Lake which is a "run-of-the-river-reservoir." Project coordinators are aware of the tendencies of newly released fish to be entrained; however, preliminary investigations at Buntzen Lake suggest that pen reared fish remain close to their release site.

Pen rearing has applications for Dinosaur Lake as a technique to acclimate hatchery fish to their new environment without having to compete for food and space. Also, hatchery fish can be pen raised until they achieve catchable size. This "put-and-take" option has the advantage of increasing the net return of hatchery fish to creel because released fish are available for harvest immediately.

3.1.3 Priorization of Methods to Reduce Entrainment

Stocking of hatchery fish in Dinosaur Lake is essential to maintain or increase sportfish numbers and improve catch rates by recreational anglers. To achieve this objective, entrainment of hatchery fish out of the system must be reduced. A modified stocking program may help to achieve this goal.

Pen Rearing

Pen rearing of fingerlings may be the most effective technique available to reduce entrainment of newly released hatchery rainbow trout, although no evidence is currently available to indicate that it will be successful. Pen reared fish can acclimate to their environment, can reach a greater size, and can be released when preferred food sources are available. Dinosaur Lake is well suited to fish pen culture, as its high flow-through rate will maximize oxygen levels, flush wastes, and decrease disease problems. It may be best to approach this option as a pilot study which, in the short term, will yield some angling benefits and an interesting visitor display.

A major disadvantage of this technique is the location where it can be utilized (i.e., Bullrun picnic area near Peace Canyon Dam). Fish released directly from pens will be susceptible to entrainment due to their proximity to the dam; as a consequence, they should be transported up to the Bennet Dam tailrace for release.

Other disadvantages are increased costs due to initial capital expenditures (i.e., holding pens), purchase of feed and the requirement of staff to maintain the stock. Higher returns to the creel of pen reared fish may offset these increased expenditures. One other disadvantage pertains to a reduction in the aesthetic quality of the sport fishery. A portion of the angling public may perceive a put-and-take fishery as artificial, a characteristic which deters from their angling experience (Hildebrand and O'Neil 1992).

Release Location and Schedule

Current release locations are the best sites for hatchery fish. The Bennett Dam tailrace creates the greatest distance between released fish and the Peace Canyon Dam which ensures some time for fish to acclimate. The inlets of Johnson and Gething creeks are also good locations due to the calm water which allows fish to acclimatize to their new environment.

The current release schedule (early June) should be maintained. Release of hatchery stock when preferred food sources (i.e., winged insects) are available in early June, allows hatchery fish to forage immediately upon release.

Fish Stock

Rainbow trout is the most appropriate species available for stocking in Dinosaur Lake; however, different strains may vary in their tendency to move down river upon release. If possible, a strain with non-migratory tendencies should be selected. Fish size also is a factor which may influence entrainment tendencies. Attempts should be made to stock larger size-classes which are physically capable of maintaining position in the riverine environment of Dinosaur Lake.

3.2 METHODS TO INCREASE RESERVOIR REARING HABITAT

A primary function of artificial structures is to concentrate desired species of fish for capture; however, they also provide shelter and a surface for attachment of fish food organisms (Prince and Maughan 1978; Brown 1986). In Dinosaur Lake, structures would provide rearing habitat which is severely limited in the reservoir. Development of "structure" may have an important benefit of reducing tendencies of hatchery fish to move downstream and out of the system.

3.2.1 Bottom Shelters

Bottom shelters have been utilized extensively in the southern United States to provide habitat diversity, areas for colonization by periphyton and aquatic invertebrates, and cover for fish (Manges 1959; Jones 1970; Prince and Brouha 1974, and others). Bottom shelters are a cost effective method to increase fish habitat. Construction materials are durable, easily accessible, relatively cheap, and require low maintenance. Unfortunately, for bottom shelters to be effective they must be located in relatively shallow water on flat or moderately sloped hard bottoms. Due to the topography of Dinosaur Lake, suitable locations are extremely limited for use of this type of structure. The following provides a brief description of the types of bottom shelters which are available.

Brush Shelters

Prince et al. (1977) describe two types of brush shelters — individual trees or brush bundles, which are weighted with concrete blocks and allowed to sink to the bottom; and brush assembled within a log crib, secured with wire, screening, or sapling poles and weighted.

The durability of brush shelters has not been studied extensively. Brush shelters installed in 1937 in Michigan were still functional in 1968 (Thomas and Bromley 1968). Other authors, however, claim that

brush shelters deteriorate rapidly (e.g., Forshage and Bonn 1977; Prince et al. 1977). In Dinosaur Lake, cool water temperatures would probably impede their deterioration.

Prince and Brouha (1974) estimated the total cost, excluding labour, of a brush shelter made of trees (three or four) at $5.00 per unit in 1973. This value would appear to be valid for all types of brush shelters that involve merely securing and anchoring the brush. A frame-type structure built with 190-L gas drums and wooden poles was estimated to take two man-days to construct (Manges 1959). No materials or labour costs were reported for construction of a log crib type shelter; however, it is estimated individual units constructed in Dinosaur Lake would be substantially more expensive than simple brush shelters.

Concrete Block Shelters

Concrete building blocks also are utilized as bottom shelters. Since the blocks have a large surface area, they are especially suited for colonization by periphyton and aquatic invertebrates. An advantage of concrete blocks over brush shelters is that these structures have a greater longevity and will not float or move. The disadvantage of concrete blocks is transport of the heavy material to the site. The blocks either can be placed in a pile by themselves or utilized in conjunction with weighted brush bundles (Prince et al. 1977). The block structures when used alone, should be placed on firm substrate so they do not sink into the bottom and become ineffective.

Tires

Automobile tires have proven to be one of the best materials for use in construction of shelters. They are cheap, durable and easily manipulated. Unfortunately, recent research has indicated that contaminants which are released by tires can harm aquatic organisms (BAR Environmental 1992). As such, it is not recommended that discarded tires be used for construction of shelters.

3.2.2 Floating Shelters

Many fish species tend to congregate around floating objects, such as logs, mats of vegetation, and docks. Helfman (1979) documented a positive linear relationship between the absolute number of fish attracted to a styrofoam float and the size of the structure. Floating objects also act as attachment sites for periphyton and invertebrates thus providing feeding locations for fish. Floating shelters serve the same purpose as bottom shelters in Dinosaur Lake, in that they provide cover which is severely limited. They are most suitable in deep waterbodies with steep bottoms which restrict use of artificial bottom shelters.

Shoreline Timbers

Large timbers anchored along selected shoreline sites is a cost effective and practical means of providing cover on the water surface. Floating timbers in the form of single logs or rafts are fastened to the shoreline with cable. These structures are relatively inexpensive to build if local materials are used, but maintenance costs can be high if shoreline anchor locations are not secure. Sufficient slack should be placed in these cables to account for water level fluctuations in the reservoir. Sites selected for floating timbers should be placed in locations which are protected from severe wave action to increase their longevity.

Midwater Structures

Midwater structures provide similar habitat as floating timbers, but are not subject to damage from wave action. These structures can be constructed of plywood or scrap timber; the most important component (and the most costly) is the flotation device. Flotation devices can be constructed from a variety of materials, such as styrofoam or air-filled canisters. Midwater structures potentially are more effective as periphyton attachment sites than bottom structures because they are closer to the water surface.

Floating "Littoral" Structures

Floating structures could be utilized to develop an artificial floating "littoral" area. Rafts or floating racks, from which a number of substrates are suspended by lines, solid rods, or wires, could be utilized for this purpose. This technique is similar in design to the procedure used in Japanese oyster culture; however, we know of no previous utilization of this type of structure for creation of rearing habitat in reservoirs. It appears to be a potential method to provide additional production of invertebrates and periphyton and to provide fish with cover. Floatation devices could be small, solid platforms, or log booms could be used to form larger structures. Substrates suspended from these floats could be constructed similar to multiple-plate macroinvertebrate samplers (as described by Hester and Dendy 1962; McDaniel 1974), consisting of circular or rectangular plates closely spaced together. Costs associated with construction of this type of structure are high relative to the other floating structures described.

3.2.3 Priorization of Methods to Increase Rearing Habitat

Very little is known about the interaction of northern fish species with artificial structures. Most enhancement projects dealing with artificial structures have been conducted in the southeastern United States or

in marine environments. No information specifically dealing with use of artificial structures in British Columbia or other northern regions was encountered.

The major factor limiting the suitability of bottom shelters in Dinosaur Lake is its steep bottom topography. In order to provide the best environment for the production of benthic organisms and periphyton, and to provide suitable rearing habitat for fish, enhancement structures would be most effective if installed in relatively shallow water.

Another major factor which must be considered is structure durability. Damage to floating structures by ice formation is not considered a problem in Dinosaur Lake; however, wave action and fluctuating water levels may damage these devices and reduce their longevity. A more serious concern is the potential of brush shelters or floating structures to loosen their moorings and enter the intake ports of the Peace Canyon Dam turbines. Annual maintenance is required to mitigate these problems.

There is a paucity of information available on structure effectiveness for enhancing the species presently in the reservoir. Most research has been conducted on the effectiveness of structures for enhancing warm water sport fisheries. As a result, most structures identified as being suitable for use in Dinosaur Lake should first be constructed on a small scale, and their effectiveness and durability evaluated prior to large scale implementation.

It also should be noted that artificial structures should be placed in areas so they do not detract from the aesthetics of the scenery provided by the reservoir.

Two types of artificial enhancement structures are suitable (based on potential benefits, costs, and maintenance factors) for use in Dinosaur Lake. These are shoreline timbers and brush shelters. A large number of structures could be built and deployed relatively cheaply.

Shoreline Timbers

The use of floating timbers anchored along selected shoreline sites would be the most cost effective and practical means of providing habitat. Use of floating structures secured to the shoreline removes the need for shallow water depths and moderate slopes.

Brush Shelters

Brush shelters appear to be an applicable cost-effective habitat enhancement technique for use in Dinosaur Lake, especially for providing habitat to newly released hatchery rainbow trout. Brush shelters should be placed in areas of moderate slope and on hard bottom sites devoid of natural cover. Although sites with moderate bottom slopes and depths <5.0 m are extremely limited in Dinosaur Lake, two potential locations include the entry inlets of Starfish and Johnson creeks.

In order to enable fishermen to realize the maximum benefit from the brush shelters, their locations should be marked with buoys or signs.

3.3 METHODS TO IMPROVE SPAWNING HABITAT

Enhancement options presented in this section have been derived mainly from recommendations made during previous studies by Thurber Consultants (1975) and Ash (1976). These recommendations are directed at increasing natural recruitment of rainbow trout, and bull trout — two species which traditionally have had wild populations in the Dinosaur Lake watershed. It is unlikely that improvements to spawning habitat for wild fish will significantly increase fish numbers in the reservoir. In addition, habitat enhancement will require large cash expenditures to properly achieve its objectives. However, the current status of tributaries utilized for spawning purposes by rainbow trout (Johnson Creek) and bull trout (Gething Creek) indicates that recruitment by natural reproduction is minimal. Poor recruitment may lead to local extirpation of these wild stocks, particularly the small population of bull trout which currently inhabits Dinosaur Lake. If conservation of wild fish stocks is a high priority, then these habitat enhancement options should be given serious consideration.

3.3.1 Habitat Enhancement

Watershed Management of Johnson Creek

Current logging practices and road construction in the Johnson Creek watershed has caused significant degradation of spawning habitat in this stream (Plate 5). Elevated sediment loads and tendencies towards flash floods have been attributed to this human activity (Hammond 1987b). To promote long-term improvement of fish habitat, these detrimental impacts should be mitigated. This would first entail an assessment of the watershed to identify problem areas (i.e., erosion of stream banks, entry points for silt-laden runoff, road crossings, etc.). Mitigation options should then be identified and implemented (i.e., reforestation, stream bank stabilization, settling ponds, slash filter windows along roads). Remedial measures required to reclaim Johnson Creek watershed will be costly, but these costs may be ameliorated by co-funding from the private sector and government agencies. Mitigative measures outlined above are essential if long-term improvement of this

tributary is to be realized. Enhancements recommended for the stream section located near Dinosaur Lake will have little effectiveness until these larger problems are addressed.

Streambank Stabilization at Spawning Sites

In order to reduce bank erosion and subsequent siltation which occurs within the lower section of both Johnson and Gething creeks, it is recommended that streambank stabilization be undertaken. This could be accomplished by installation of rip-rap material along actively eroding banks. On-site inspections are required to identify problem areas and to estimate costs required to complete this task.

Artificial Spawning Substrate

Once the high suspended sediment load and the resulting sedimentation problems are reduced, it is advisable to increase the amount of spawning substrate by placing clean gravel of suitable size in the creeks; however, this option should be considered only after the suspended sediment loads in the creeks have been reduced. At present, spawning gravel placed in the stream would be susceptible to compaction and siltation.

3.3.2 Facilitated Access

Barrier Dam on Johnson Creek

Prior to creation of Dinosaur Lake, a set of falls in lower Johnson Creek acted as a barrier to the upstream movements of all fish species except rainbow trout. This permitted rainbow trout to utilize Johnson Creek for spawning and rearing without competition from other fish species. After reservoir inundation, the lower falls were flooded thereby extending the range of several species of fish in Johnson Creek including longnose sucker. This may have resulted in greater competition for spawning sites between rainbow trout and longnose suckers. This species may affect trout spawning success by utilizing holding areas which would otherwise be available to rainbow trout, by destruction of redds, by predation on the trout eggs and fry, and by competition for food.

To prevent longnose suckers from gaining access to Johnson Creek, a low-head barrier dam at the full supply level could be installed. This type of structure would prevent the upstream movement of undesirable species. The height of the barrier dam should be as low as possible, but still prevent passage of undesirable species while allowing passage of rainbow trout. At the same time, it should pool the least amount of water upstream of the structure to limit inundation of potential spawning habitat.

Plate 5 Typical logging activity adjacent to stream course in Johnson Creek watershed, August 1975.

The construction of the dam should include two features to permit passage of adult rainbow trout upstream and juveniles downstream. These include: 1) an undercut plunge-pool immediately below the weir to allow the formation of a standing wave of turbulence from which trout can easily leap upwards, and 2) an inclined plane on the upstream edge to permit natural downstream movement. The dam should also be strong enough to withstand flood events which frequently occur on this creek.

Disadvantages associated with this method include high capital and labour costs required to build the structure. As well, sub-adult rainbow trout would not be able to enter Johnson Creek to rear during the summer period. This stream is one of the few rearing areas available to rainbow trout in Dinosaur Lake, particularly for hatchery fish. Conversely, this may reduce competition for rearing habitat for wild stock rainbow trout, thereby increasing their survival.

The installation of a barrier dam also may impound a short upstream section of stream. This may cause erosion and slumping of the bank into the creek, possibly resulting in a diversion of the creek around the barrier dam. It is recommended that this problem be investigated prior to implementation of this option.

Access to Gething Creek

Installation of facilitated access structures in Gething Creek would considerably increase the area available for spawning to bull trout and rainbow trout. In order to allow unobstructed passage of these species into the upper section, a total of four structures would be required. Due to the entrenched nature of Gething Creek, it is doubtful the benefits produced would justify the high costs of construction and serious logistical constraints.

An alternate less expensive method to facilitate access to upstream sections of Gething Creek has been described by Ted Down of B.C. Environment. Mature fish which enter the creek to spawn could be captured and physically transported upstream and released. Spawning bull trout which are known to concentrate in the plunge pool at the base of the first impassable falls are easily captured (Hammond 1984). Collected fish could then be air lifted by helicopter and released upstream. Once spawning has been completed, adult fish will return to the reservoir. Juvenile fish, after residing in Gething Creek for two to three years, also likely will migrate downstream to enter Dinosaur Lake. This option also may be applicable for spawning rainbow trout; however, low fish numbers, high spring flows, and high turbidity will make capture of rainbow trout difficult.

Transport of spawning fish around physical barriers which block migration is an often utilized mitigative technique. Between 1989 and 1991, significant numbers of rainbow trout and bull trout were captured immediately downstream of the Oldman River Dam construction site (located in southwestern Alberta) and successfully transported 20 km upstream (EMA/R.L. & L. 1992,1993).

The suitability of Gething Creek as spawning and rearing habitat upstream of the fish barrier should be investigated before facilitated access can be considered. Ash (1976), during a preliminary investigation of the Gething Creek watershed, identified suitable spawning and rearing habitat during mid-summer; however, no fish were captured during intensive sampling, indicating that a resident population of fish was not present in the creek above the falls. Availability of critical habitat for spawning bull trout should be documented. Work done by R.L. & L. Environmental Services Ltd. on two spawning streams in southwestern Alberta suggest that deep holding water and/or overhead cover adjacent to the spawning substrate are important criteria for site selection by bull trout (R.L. & L. unpublished data). Overwintering habitat (i.e., low velocity, deep water areas, groundwater sources) also must be available to ensure survival of rearing fish. If these critical habitat features are not severely limited, facilitated access may be a viable option to increase natural recruitment into wild populations.

3.3.3 Artificial Spawning Channels

In order to maximize the reproductive potential of rainbow trout inhabiting Dinosaur Lake, it may be advisable to construct artificial spawning channels. Clay (1961) cited a number of studies which indicate that artificial spawning channels can greatly increase the survival of salmonid eggs and fry compared to natural stream conditions. One site previously suggested as a possibility for an artificial spawning channel by Ash (1976) is located at the base of the Bennett Dam. Water could be taken from the discharge canals and diverted to flow through a series of gravel beds arranged in "steps" down to the reservoir level. Wightman and Taylor (1978) stated that a spawning channel at this site, although not an engineering impossibility, was intuitively considered biologically high risk and probably extremely costly by virtue of its proposed location and site physical constraints. More importantly, the suitability of water temperatures in the tailrace should be investigated before this site can be given serious consideration.

One other potential site exists at the Bullrun Flats picnic area near Peace Canyon Dam (Plate 6). During 1989, preliminary investigations were conducted to assess the impact of diverting Bullrun and Portage creeks into the picnic area drainage channel leading into Dinosaur Lake (Appendix B). This diversion was contemplated as a way to increase power production and to provide additional spawning habitat to Dinosaur Lake sportfish. These investigations suggested that the project may be worthwhile.

Bullrun and Portage creeks would be diverted into the drainage channel to create sufficient discharge during spawning and rearing periods. A water control structure at the head of the channel would control inflow during peak discharge. High quality spawning substrate and possibly an impervious liner under the channel would be required. Creation of this artificial channel would also provide a rearing area for fry, as well as sub-adult fish which would move up from the reservoir.

Plate 6 Drainage channel at Bullrun Flats picnic area near Peace Canyon Dam, July 1989.

An additional benefit associated with this option will be public education. The channel is situated adjacent to the existing picnic area which provides good potential for viewing and an interpretive display. A serious drawback associated with use of this site is its close proximity to the intake ports of the Peace Canyon Dam. This would increase the possibility of entrainment of young-of-the-year fish which enter the reservoir. Addition of artificial structures in the vicinity would help prevent fry from being entrained.

3.3.4 Priorization of Methods to Enhance Spawning Habitat

Spawning habitat enhancement will provide benefits to the wild sportfish populations, principally rainbow trout and bull trout, in Dinosaur Lake. Costs associated with habitat restoration and creation will be high and the increased level of recruitment will probably not be sufficient to significantly increase current population levels. Also, if problems associated with lack of rearing habitat in the reservoir and entrainment of young fish are not addressed, then enhancement of spawning habitat is of little value. Habitat enhancement, however, is the only method available, outside of artificial propagation, to improve wild fish stocks in the reservoir.

Watershed Restoration of Johnson Creek

Watershed restoration of Johnson Creek has the greatest potential, in the long-term, to improve natural recruitment of wild rainbow trout. Unfortunately, this option will require an extended period of time to meet its objectives, and capital expenditures, either by the government or private industry, will be high. Watershed restoration is required to reduce the variable flow regime and high suspended sediment load in the lower section of Johnson Creek. Until this is accomplished, there is little value in enhancement of spawning habitat in the lower section of Johnson Creek.

Facilitated Access

Facilitated access of Gething Creek by capture/transport is the best option to increase recruitment to the bull trout population in Dinosaur Lake. This is applicable only if suitable habitat is available in upstream areas. It is much more cost effective than construction of facilitated access structures and would provide more benefits than enhancement of spawning habitat in the lower section of Gething Creek.

Artificial Spawning Channels

In the short term, spawning habitat for rainbow trout should be enhanced by creation of a spawning channel at Bullrun Flats. A detailed assessment of environmental conditions, costs of construction, and maintenance is required before this option can be given serious consideration.

3.4 SUMMARY

Implementation of enhancement alternatives to mitigate constraints will be costly and their effectiveness cannot be predicted with absolute certainty. The choice of which enhancement option to implement depends on the long-term management goals for the reservoir. If increasing sportfish densities to improve recreational angling in the reservoir is important, options designed to reduce entrainment should be given highest priority. If maintenance of wild rainbow trout and bull trout populations is critical then spawning habitat improvement of the tributaries should be given serious consideration.

The major limitation of Dinosaur Lake is its severely restricted rearing habitat and entrainment of fish out of the reservoir. To increase fish numbers in the reservoir these problems must be addressed (Figure 2). Stock manipulation and pen rearing of hatchery fish may be the most cost-effective methods to reduce entrainment but they do not address the problem of severely limited rearing habitat. Use of artificial structures, although expensive if utilized on a large scale, is the best method available to create habitat in a reservoir such as Dinosaur Lake. Both alternatives should be implemented to enhance the reservoir fishery.

Once problems of entrainment and lack of rearing habitat in the reservoir are addressed, the alternatives described to enhance spawning habitat should be investigated. An artificial spawning channel at Bullrun Flats would provide the most cost-effective method to increase spawning habitat for reservoir fish populations. To conserve wild fish stocks, habitat restoration of both of the major tributaries is essential. Tributary restoration should be considered as a long-term objective due to the significant costs and time required. Restoration of spawning habitat in tributaries has the added benefit of improving rearing habitat. In the short-term, capture/transport of spawning bull trout is an appropriate measure to improve recruitment and mitigate the potential for local extirpation of this species.

Costs associated with all enhancement options can be significantly reduced by inclusion of volunteer participation during construction and maintenance phases of these programs. Organizations such as local fish and game clubs, Trout Unlimited Canada, and community groups can be an integral part of enhancement projects in western Canada. Various chapters of Trout Unlimited Canada are currently involved in the design, implementation and maintenance of several stream restoration projects in Alberta and British Columbia (Gary Szabo, Trout Unlimited Canada, pers. comm.). Not only does volunteer participation reduce costs, but their involvement promotes public awareness and good communication between government agencies and the community.

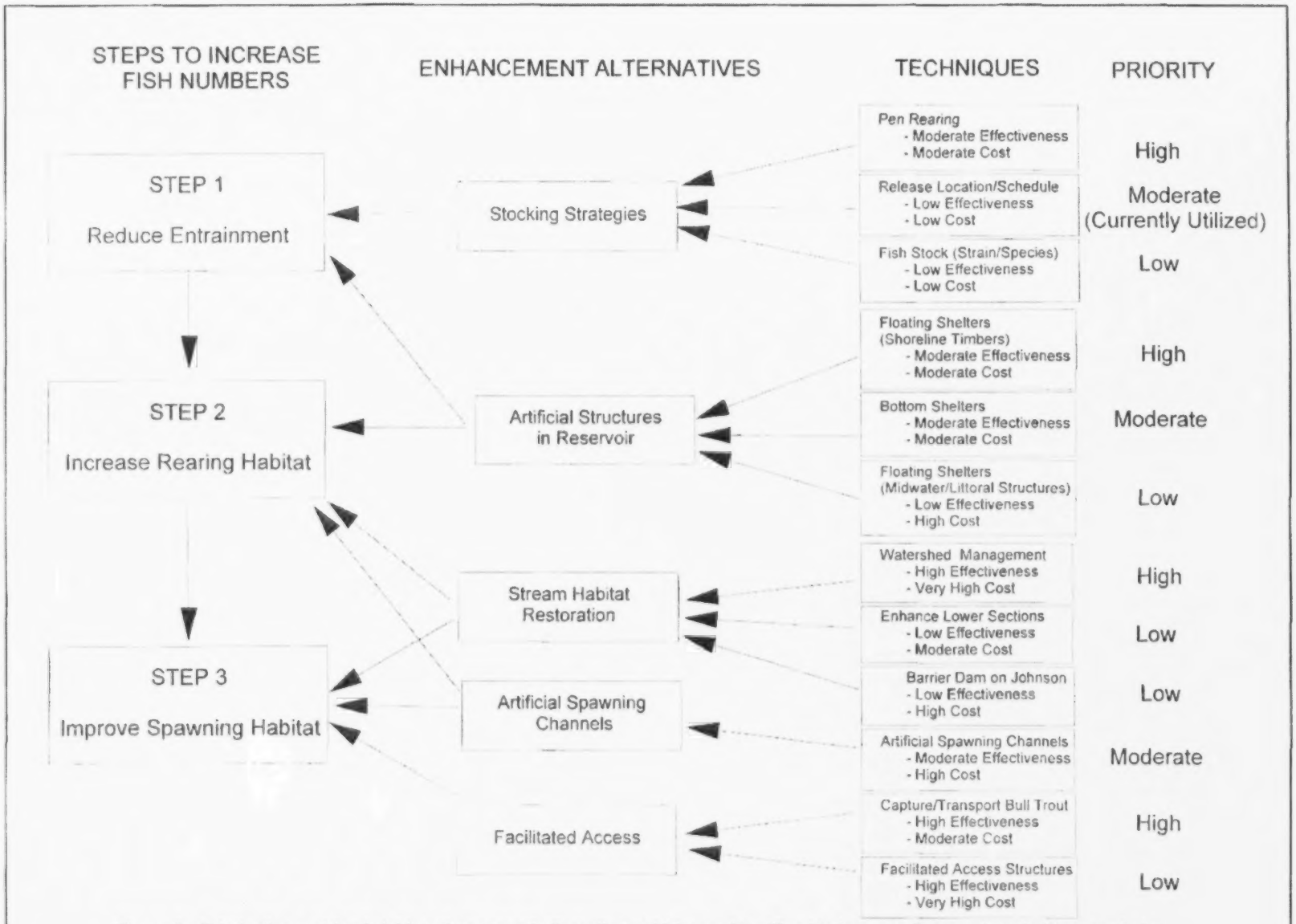

Figure 2. Priorization matrix of viable enhancement alternatives which may be utilized to increase fish numbers in Dinosaur Lake.

4.0 RECOMMENDATIONS TO ADDRESS DATA GAPS

If fisheries enhancement of Dinosaur Lake is to proceed, steps should be taken to address a number of critical data gaps which exist. They include an update of biophysical inventories of Dinosaur Lake and its major tributaries, as well as detailed cost-benefit analyses of fisheries enhancement options.

4.1 BIOPHYSICAL INVENTORIES

Dinosaur Lake

Biophysical inventories of Dinosaur Lake were last completed in 1986. At that time fish populations in the reservoir were in a state of flux with species such as lake whitefish and longnose suckers exhibiting drastic shifts in abundance. It is important to assess present fish community composition and abundance in the reservoir. This will identify important changes which may have occurred since 1986. For the same reasons water quality parameters and food resources (i.e., Zooplankton densities) should be investigated.

Tributaries

Johnson and Gething creeks are the only major spawning and rearing areas for wild sportfish populations in Dinosaur Lake. Habitat conditions below the falls and the extent of fish use should be investigated. Current use by wild fish populations (i.e., rainbow trout and bull trout) also should be assessed. Before enhancement of Johnson Creek or Gething Creek can be considered, present conditions of these watersheds and their fish populations should be inventoried. Questions to be addressed include areas requiring immediate reclamation, species composition and abundance of resident fish stocks, and important rearing and spawning areas.

4.2 COST-BENEFIT ANALYSES OF ENHANCEMENT OPTIONS

Detailed cost-benefit analyses of enhancement options were beyond the scope of this study, and cannot be completed until detailed site-specific information is available for many of the options. Before alternatives outlined in this report can be given serious consideration, cost-benefit analyses should be completed. These analyses should incorporate use of local materials and volunteer labour as means to reduce costs.

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APPENDIX B

Information Concerning Bullrun and Portage Creeks

FISHERIES RECONNAISSANCE OF BULLRUN AND PORTAGE CREEKS

Prepared by Gary R. Ash
R. L. & L. Environmental Services Ltd.

14 November 1989

A reconnaissance of Bullrun and Portage creeks, located near Hudson's Hope, was undertaken on 8 November 1989 to assess fisheries potential of the creeks, and to assess the impacts of diverting the two creeks into Dinosaur Lake. The diversion proposal is the result of a submission under the B.C. Hydro Employee Suggestion Program.

PORTAGE CREEK:

Portage Creek originates to the west of the Peace River, and enters the Peace River below the Peace Canyon Dam at a point just upstream of the Hwy. 29 bridge. The creek flows over the edge of the Peace Canyon rock wall, and plunges over 30 m down to the Peace River (Plate 1). As a result, their is no interchange of fish between this creek and the Peace River. Prior to entering the Peace River, the creek flows through the previous construction site adjacent to the Peace Canyon Dam, and presently flows through culverts under the main access road to the dam, and also under the access road to the viewpoint.

Passage under the viewpoint road is through two 1.7 m (approx.) culverts. At the time of investigation, the flow was principally through the right (looking upstream) culvert, with just a small trickle through the left culvert. Below the culverts, the creek was about 1.5 to 2 m wide, and had a maximum depth of about 15 cm. The water was clear and cold (temperature of 0.5 degrees Celsius at 1310 h). The substrate was composed primarily of rock and gravels, although some small silted pools were also present.

Upstream of the viewpoint road, the creek flows through a relatively steep gradient section. This area was previously cleared and is now vegetated with a dense growth of young poplar trees. In this section, the creek varied from about 0.5 to 1.5 m in width.

At the main access road crossing, the creek flows through two 1.7 m (approx.) diameter culverts. The creek was not investigated upstream of this point.

As mentioned above, Portage Creek is not utilized by fish from the Peace River; however, at the time of investigation, the flow in the creek suggests that it is spring fed, and likely flows all winter. It is possible, therefore, that it may support a resident fish population, although no fish were observed at the time of investigation. Prior to final approval for diversion, it is recommended that an electrofishing survey be conducted to determine if any resident fish population is present. Assuming that the creek does not support a resident population, there would be no fisheries concerns with diverting Portage Creek into the Dinosaur Lake. It should be noted, however, that the falls where the creek enters the Peace River is scenic, and is visible from the Hwy. 29 bridge. As a result, there may be some social concerns with regard to the diversion plan which should be addressed.

BULLRUN CREEK:

Bullrun Creek also originates to the west of the Peace River, and now flows through a highly eroding channelized section along the powerline right-of-way, under the access road to the recreation area on Dinosaur Lake, under the main access road to the dam, and over the edge of the bank just downstream of the Peace Canyon Dam. The creek also crosses under the tailwater pumphouse access road before entering the Peace River.

Above the campground road, the creek was about 0.5 to 1 m wide and 15 to 30 cm deep. The substrate was primarily sand/silt reflecting the highly eroding banks throughout this channelized section. The water temperature at 1345 h was 0.5 degrees Celsius.

Due to the small size of this creek, and the poor habitat conditions in the channelized area, this section of Bullrun Creek was considered to have no potential to support sportfish populations. As a consequence, there are no aquatic concerns with diverting the creek into Dinosaur Lake.

ENHANCEMENT POTENTIAL

At the present time, there is an intermittent creek along the edge of the campground area on Dinosaur Lake. This creek has been channelized, to direct flows around the campground and into Dinosaur Lake above the boat launch. This section has been protected through armouring the bed with gravels to prevent erosion. At the time of the investigation, there was no flow in the creek, and a gravel sill had formed at the edge of the reservoir.

With proper design (eg., possibly requiring greater meandering to reduce the gradient) and the diversion of Bullrun and possibly Portage creeks via this drainage into Dinosaur Lake, it may be possible to create some spawning and rearing habitat for rainbow trout in the reservoir, thereby providing some benefits other than power production from the diversion of the creeks. At the present time, the lack of suitable spawning and rearing habitat currently limits fish production in the reservoir. To further evaluate this potential, the system should be investigated in the spring (late May) by a fisheries biologist and a hydraulic engineer. This would allow an assessment of freshet flows and assessment of possible design for the creation of spawning and rearing habitat.

PERMIT REQUIREMENTS

Prior to diverting the creeks, discussions of the proposal should be conducted with Ministry of Environment staff, and appropriate permits obtained.